SCHOOL HEATING AND VENTILATION—A STUDY IN APPLIED PHYSICS

Too many experiments in elementary physics are performed from the standpoint of the "science," too few concern directly the topics in which the boys and girls are interested because they are immediately practical or related to common experience. Great progress already has been made in the elimination of meaningless, quantitative, experiments. The reorganization of the experimental work so as to emphasize the practical and the applied aspects of physics must follow if this subject is to occupy its rightful place in secondary education. This paper describes one example of such applied work which proved stimulating and instructive to a class.

The great increase in the number of students has resulted in the erection of great high-school buildings which offer unequaled opportunities for the practical study of the problems of heating and ventilation. Almost all high-school buildings have systems of forced ventilation, differing widely in principle and still more in efficiency. The thorough testing of such systems by a physics class not only provides interesting, practical work for the class, but may also prove of direct service to the school community. Definite knowledge of the shortcomings and inefficiency of a system may not mean the installation of a new and adequate one, but very often much improvement may result in practice through the suggestions which a physics class is able to make after a comprehensive survey.

The pupils were first asked to make a study of the heating-plants in their own homes and at the next recitation to report to the class the results of their investigation. The common methods of hot-air, hot-water, steam, and vapor heating were studied in this way by first-hand methods. Pupils of former years had prepared large colored diagrams illustrating these fundamental systems, and these were used in the class discussion. They served in some cases to correct wrong impressions, and in others to bring out interesting modifications of heating plants which investigation at home had revealed. The discussion of the advantages and disadvantages, the cost of installation, the conditions under which each system is most efficient, was spirited and showed the interest which this personal contact aroused. A diagram

of the home system, with suitable explanation, was required in the notebook of each pupil, and counted as a regular laboratory experiment.

The study was then extended to the school heating system. This is probably unique, from the fact that three different principles are utilized. The school lunchroom and library are in a separate building, which is heated by a furnace; the school proper is heated by steam, while the basement rooms, used as shops and laboratories, are heated by hot water, the condensed steam flowing through these radiators on its return to the boilers. In addition, the ventilation system employs the indirect use of steam heat to warm the air drawn in from out of doors. A study of the school system thus gives opportunity to every pupil by direct observation to become familiar with the three common methods of heating.

The problem of ventilation was then discussed by the class and defined as follows: "Good ventilation means the adequate supply of fresh clean air at a proper temperature, the removal of the used and foul air, and the maintenance of a proper amount of water vapor in the air of all rooms." The methods of home-heating were then reviewed to see how they assisted in securing adequate ventilation. The problem then put before the class was an investigation of the efficiency of the school ventilating system.

The school plant was studied that the class might understand its work. In the attic a powerful fan draws in air from out of doors through bags that are laundered weekly. A bag which has been in place for a week is an instructive lesson to the student. The air is then warmed by steam radiators and forced down through flues to each classroom, which it enters horizontally, near the ceiling. On the same side of the room, near the floor, the vent for foul air leads up to openings in the roof. The escape of foul gases from toilet-rooms and laboratories is assisted by the use of a suction-fan, also in the attic. Incidentally, the pupils discovered that this system was not planned for when the building was constructed, but was installed afterwards. The cold-air openings, which formerly led in under the radiators, had been closed up, though their old positions were easily noted. The wisdom of attempting to force hot air down to the basement was questioned, and the effect of open windows and doors on the efficiency of the system became another question well worth investigation.

PUPILS USING ANEMOMETER AND SLING-PSYCHROMETER

The use of a standard anemometer* for determining velocity of air-currents and a sling-psychrometer for rapid determinations of relative humidity was explained to the class and a few practice deter-

*The Tycos type of instruments secured from the Taylor Instrument Company of Rochester, N. Y., was used in this work.

minations made. The class was then divided into sections, and these groups, working at convenient times, determined the number of cubic feet of fresh air entering the various rooms in the school under ordinary working conditions, the windows being left just as they were found. Since the maximum number of pupils using the room at one time was known, the number of cubic feet per person was easily found. It is generally believed that 2,000 cubic feet of fresh air are desirable hourly for each individual, and the results were judged on this basis. Other groups of pupils used the sling-psychrometer to determine the temperature and relative humidity at varying times and under varying conditions. They noted the relative location of inlets for fresh air and outlets for foul air in the various rooms, to see whether the proper circulation throughout the room was obtained. In several rooms dead air-space was in evidence. The windows throughout the school were then carefully closed, and the determinations repeated in a number of rooms, to see whether this condition would materially increase the efficiency of the system.

A member of the chemistry class was called upon to test the air in certain rooms for its carbon dioxide content, using the Wolpert carbacidometer. These tests served to complement the work of the physics class and further confirmed its results.

The following report of the class survey was submitted to the school authorities, and shows its value to the school community as well as to the pupils conducting the tests:

TABLE OF TESTS FOR AMOUNT OF CARBONIC ACID

FLOOR	ROOM	CUBIC CMS. OF AIR REQUIRED	PARTS PER 1,000 OF CO_2	QUALITY	REMARKS
Basement	Physics Lab.	27	1.19	Bad	Windows shut
Basement	German Room I	20	1.62	Very bad	Windows shut
First	Gymnasium	42	.76	Fair	Windows open
Second	Second Grade	31	1.03	Bad	Windows shut
Second	Third Grade	40	.80	Fair	Windows shut
Third	Seventh Grade	45	.70	Fair	One window open
Third	Eighth Grade	50	.63	Good	Windows open
Third	Tenth Grade	47	.67	Fairly good	Windows open

TABLE SHOWING EFFICIENCY OF VENTILATION SYSTEM

ROOM	VELOCITY PER MINUTE	AREA OF INLET IN SQ. FT.	CU. FT. OF AIR PER HOUR	MAXIMUM NO. OF PUPILS	CU. FT. PER PUPIL PER HOUR	EXCESS OR DEFICIENCY	REMARKS
Physics Lab.	128	1.421	10,913	24	455	-1545	Windows and doors closed.
German II	0	1.215	0	18	0	-2000	Windows closed, doors open.
First Grade	218	2.576	33,731	30	1124	-876	Door open.
Gymnasium north	418	4.843	121,462	322	483	-1517	Several windows slightly open.
Gymnasium south	121	4.683	33,998				
Second Grade	233	3.108	43,450	38	1143	-857	All windows slightly open.
Third Grade	261	3.108	48,671	29	1678	-322	One window slightly open.
Eleventh Grade	479	2.354	67,854	28	2423	+423	One window slightly open.
Music Room II	347	2.354	49,010	25	1960	-40	One window half open.
General Science	233	1.022	14,288	22	650	-1350	Windows and doors closed.
Music Room I	279	1.641	27,470	33	832	-1168	One window slightly open.
Art Room	356	3.108	66,387	33	2012	+12	Two windows slightly open.
Ninth Grade	337	3.108	62,843	30	2095	+95	One window slightly open.
Tenth Grade	695	3.748	156,250	49	3188	+1188	Three windows half open.*
Twelfth Grade	230	3.108	42,890	25	1716	-284	Window and transom open.

*The three open windows were immediately below the ventilator, causing a direct short-circuiting of the air currents.

TABLE OF RELATIVE HUMIDITIES*

ROOM	DRY-BULB TEMPERATURE	WET-BULB TEMPERATURE	DEGREES OF COOLING OR DIFFERENCE	RELATIVE HUMIDITY
Physics Lab.	67.5	49	18.5	22%
Chemistry Lab.	63	45	18	18%
French II	69	50	19	22%
German I	69	50	19	22%
Shop	67	49	18	23%
Kindergarten	66.5	47	19.5	18%
Gymnasium	66.5	44.5	18	19%
Third Grade	70	51	19	23%
Gen'l Science	69.5	49.5	20	19%
Eleventh Grade	66	48	18	22%
Ninth Grade	68	48	20	17%
Eighth Grade	64	45.5	18.5	18%
Fifth Grade	66	49	17	26%
Front Study	68	49	19	21%
Twelfth Grade	67	55	12	46%
Art Room	68	52	16	31%

Upon the above tables the physics class base the following conclusions:

1. The ventilation system is fairly adequate to the needs of the third floor, nearly so for the second floor, but entirely inadequate for the rooms on the first floor and in the basement.

2. The closing of all windows throughout the building does not materially increase the efficiency of the ventilation system, unless it be to make for a better circulation of air from the ventilator through the rooms.

3. The location of vents in the laboratories is poor and entirely inadequate to remove objectionable gases; in fact, it serves rather to disseminate them throughout the building.

4. The relative-humidity table shows the air throughout the school to be extremely dry, averaging less than 25 per cent, whereas it should be not less than 40 per cent. This may easily be corrected by supplying radiator pans for the rooms on the first floor and basement, and by evaporating water into the air as it enters the ventilating system. This could best be done by using an open trough heated by a steam-coil to produce rapid evaporation.

5. The temperature of air entering the rooms from the ventilating system is not adequately controlled, being generally too warm. Warm air produces a feeling of stuffiness and discomfort which is usually associated with foul air.

6. In several rooms when windows are closed the carbon-dioxide content of the air reveals the lack of adequate ventilation and in general confirms the results obtained by other tests.

*These results were obtained during a period of severely cold weather, the condition which would best reveal any failure to maintain the proper relative humidity.

7. If windows are used for purposes of cooling and ventilation, as generally is the case, the expense of operating the fan system is, from the standpoint of economy, very wasteful.

Some of the results of the class work were given to the whole school at a morning exercise and aroused much interest. This was especially true in the fourth grade, where considerable time was spent in studying common methods of heating, repeating some of the simple experiments which had been performed in the morning exercise, and using the colored diagrams of the different systems. As a lesson in English as well as in science the whole grade was asked to write a description of these experiments and an explanation of what they showed. The paper which was selected as the best is given below in full.

No. I

We placed a candle upright on a saucer, and a triangle around the bottom of the candle. Then we placed a lamp chimney over the candle, so it rested on the triangle. In this way a draft came through the chimney from the bottom. A piece of lighted punk was put under the chimney, and the smoke rose through the chimney and came out at the top. This showed that there was a draft from the base of the chimney through it.

No. II

For this experiment we used the same apparatus as before, only the triangle was removed and the chimney rested on the saucer, which was filled with water, thus sealing the base of the chimney. The candle flickered and gradually went out. This shows that fire needs air.

No. III

The same apparatus was used as before; also a piece of cardboard put upright in the chimney, dividing it in half. This time the candle did flicker a bit, but it did not go out. This is because there is a circulation or air going in at the top at one side and out the other. This was proved by placing lighted punk at one side. The smoke went in and down that side and up and out the other. Henry.

Groups of pupils in the fourth grade studied further the different systems of heating and prepared the following statements, which were submitted to the physics class for correction:

HOT-WATER HEATING

Hot water is one system of heating. Water comes from the city main through underground pipes to different houses. Then the water goes through pipes that circle round the inside of the furnace. The water is then heated and goes up into the pipes that lead to the radiators. The reason for this is that hot water expands. Then the water goes up to the first floor and the second floor, and so on. The water expands and rises, thus heating the dif-

ferent floors. When the water expands, it must have some place to expand into, so there is an expansion-tank on the top of the roof, and if the expansion overflows, there is a pipe leading to the sewer. If the water is cold when it leaves the radiator, it goes down and is reheated by the same heating process as before.

The steam heating is much cheaper, because only one set of pipes is needed, while in the hot-water heating two sets of pipes are needed. One of the advantages in hot-water heating is that the air is not so dry as steam heating, and also it can be regulated more easily.

Robert, Mildred, Elizabeth, Walter,
Edward, Marianne, Van.

The character of this fourth-grade work reveals the general interest in the problems of heating and ventilation aroused in the whole school by the work of the physics class and is further proof of the value of such a study to the school community.

HOT-AIR HEATING

Hot air is one of the ways of heating. The cold air enters in through the cold air inlet and is heated around the fire jacket. After it is heated, it passes through different parts of the house by means of pipes. Hot air rises, so as soon as the air is heated it goes up through the pipes into the rooms. When the air cools, it goes down the foul-air vent and into the furnace, and is carried with the smoke up the chimney. This system is used only in small buildings. It is less expensive than other systems.

Barbara, Ruth, Margaretta,
Lizette, Caroline, Margaret,
Preston, William.

STEAM HEATING

The steam-heating system is cheaper than most heating systems, because only one set of pipes is needed. The water comes from the city main, and is then turned to steam in the water-jacket. It goes up the pipes to the radiators. Then it circulates in the radiators. There is a valve at one end of the radiator to let the cold air out, so the hot steam will have room to get in. The steam condenses, and the water then goes down the same pipes that the steam comes up. When the water turns down the sharp corners, it makes the pounding noise that is often heard. When it gets down to the water-jacket, it is reheated.

Barrett, Peggy, Grace,
Eleanor, Juniata, Albert.